

HamSci

March 2020

Aurorasaurus: Citizen Science Observations of the Aurora

Dr. Liz MacDonald

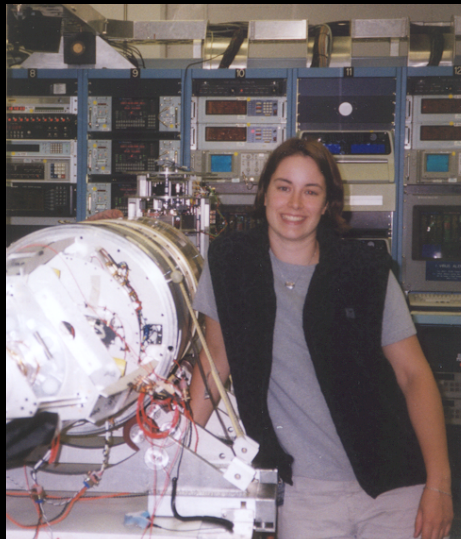
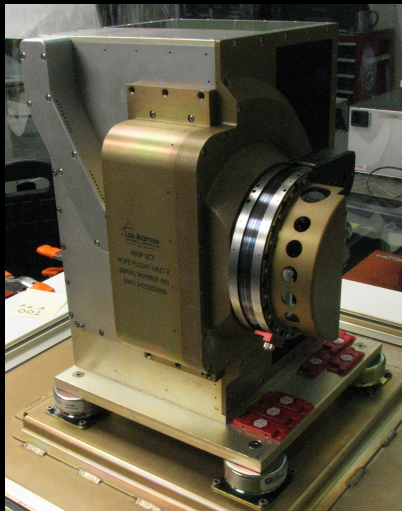
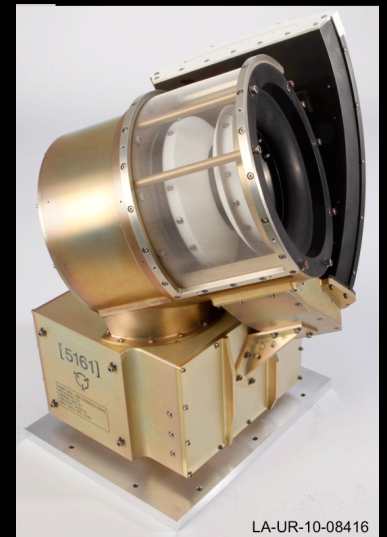
Aurorasaurus founder, NASA Goddard
Heliophysics Citizen Science Lead, NASA HQ



Photo: Mt. Assiniboine and STEVE by Jun Wang, Alberta Aurora Chasers, American Scientist magazine

Who
am
I?

@spaceyliz



Now you know a little about me, I'd like to learn a little about you

- How many have seen aurora?
 - Half of the scientists have not
- How many are familiar with citizen science?
- How many have done citizen science with auroras?

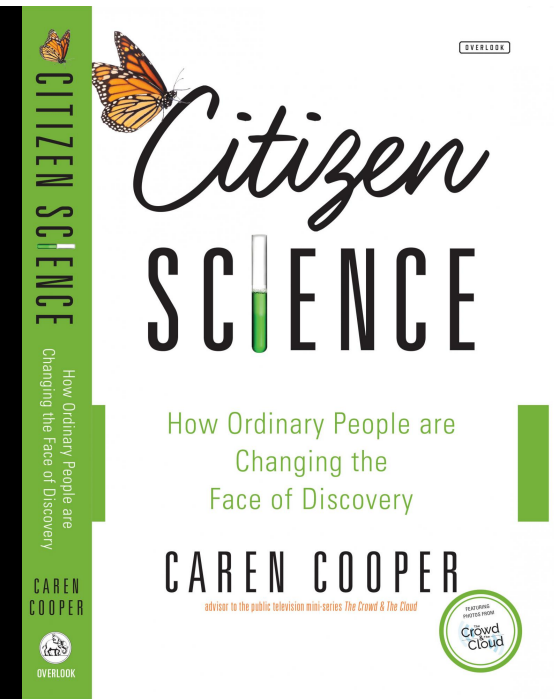
In 2011 I had a new idea about how ordinary people could help study aurora...

- What is Citizen Science?
- Why do we need help?



Nike

Aurora is not just a pretty picture,
these data are useful



- Organized research in which members of the public engage in the processes of scientific investigations
 - Asking questions, collecting data, and/or interpreting results
- Works on a massive scale & generates high quality data
 - Leading to reliable, valid scientific outcomes & unexpected innovations

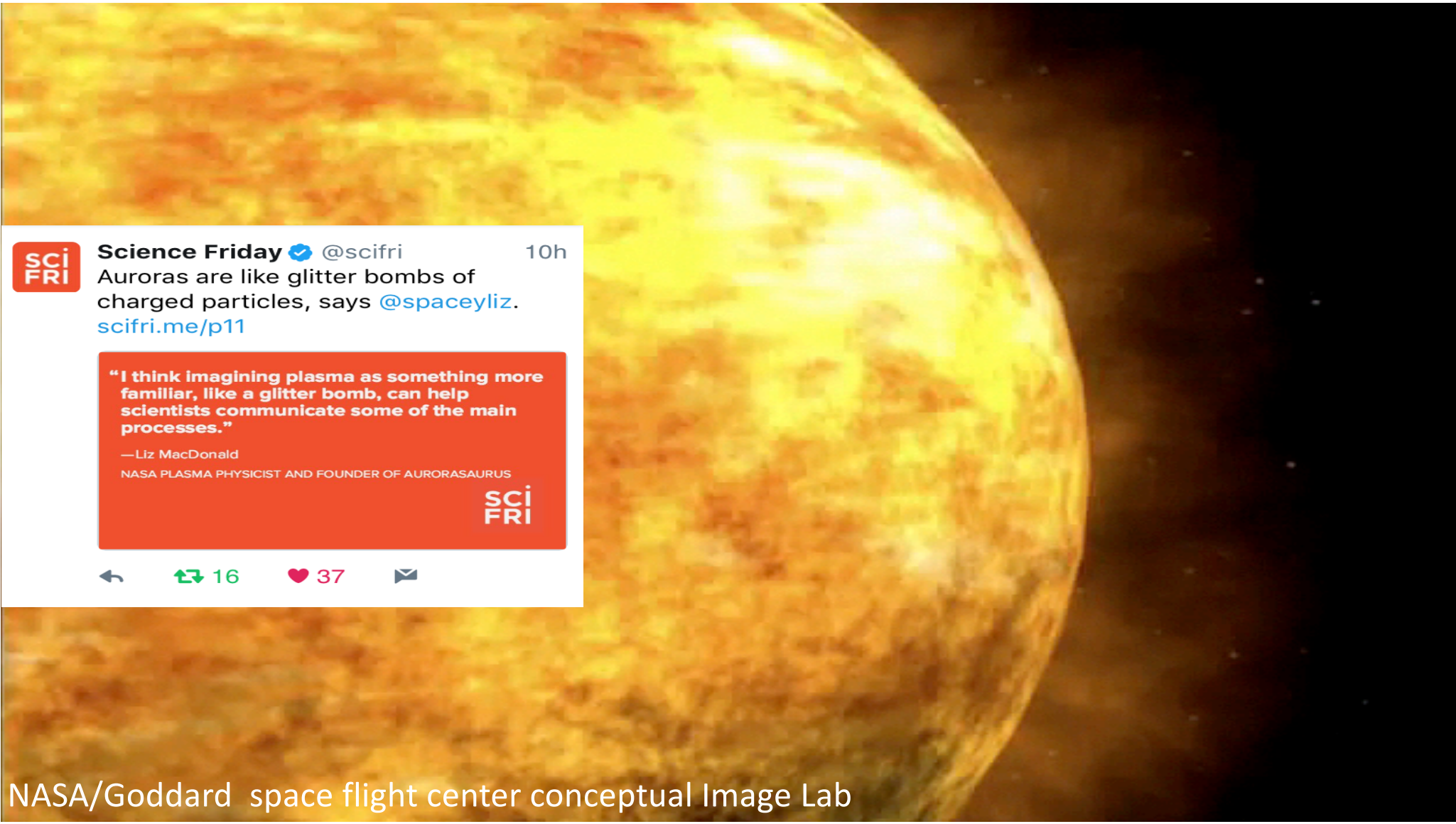
Citizen science has

- A multitude of scales and disciplines working together
- Dedicated communities & its own field of practitioners
- Terms of use / agreement for volunteer data
- Archives of data with FAIR data principles and additional concepts like interoperability of databases for multiple purposes (Laura's poster)
- Volunteer management & communication
- High quality data and controls
- Not free
- Science goals / questions appropriate to data quality

Citizen Science at NASA

- SMD has a policy encouraging citizen science (read SPD-33 guidance, bit.ly/spd-33)
 - Wherever appropriate for the science
- Heliophysics has a strategic working group on deliberate implementation of the policy
- Stay tuned! Much more to come
 - July, 2nd annual NASA citsci meeting in ME
 - Eclipse 2020 funding opportunity opened in nspires. Due date coming soon. Mentions citizen science in the call!
 - Interdisciplinary reviewing opportunities

<https://science.nasa.gov/citizenscience>



Science Friday  @scifri 10h

Auroras are like glitter bombs of charged particles, says @spaceyliz.
scifri.me/p11

"I think imagining plasma as something more familiar, like a glitter bomb, can help scientists communicate some of the main processes."

—Liz MacDonald

NASA PLASMA PHYSICIST AND FOUNDER OF AURORASAURUS



  16  37 

NASA/Goddard space flight center conceptual Image Lab

Sparse & under-sampled data



93 million miles!
(not to scale!!)

- We monitor interplanetary solar wind plasma (B field) at L1 point (ACE, DSCOVR, WIND)
- We don't know B when we look at the Sun
- Very few satellites for the amount of space to cover

Magnets, electric particles, and collisions



What causes the Aurora?

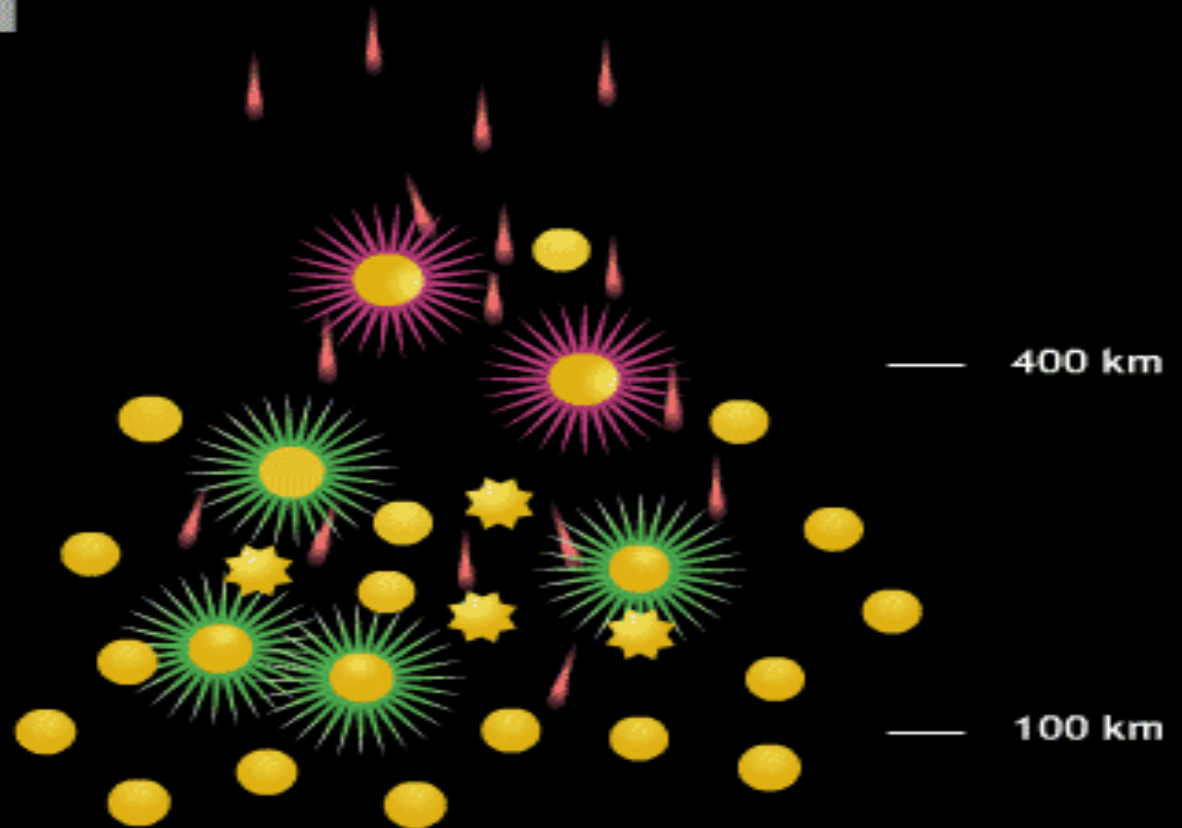
electrons hit
air molecules



molecules
are "excited"



molecules
give off light as
they calm down

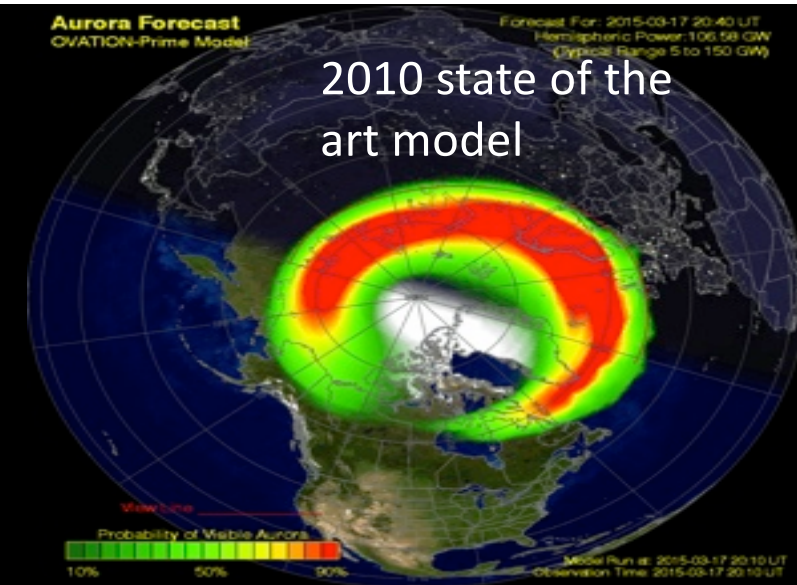


The importance of Heliophysics

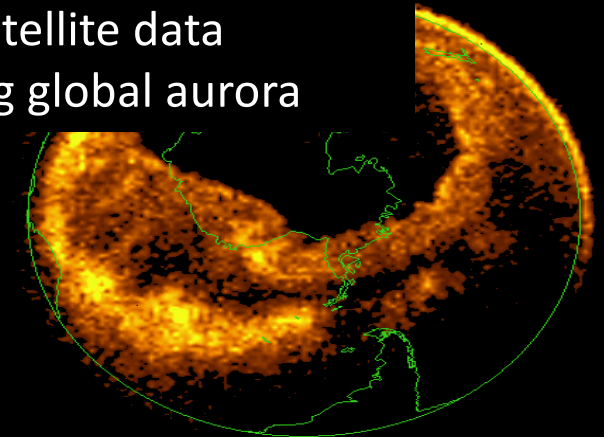
- Science gaps
 - The evolution of aurora during large storms never fully characterized
 - Aurora are universal acceleration processes and our monitors are very sparse

**Space Weather has billion \$\$
impact potential:**

GPS, ground induced current,
spacecraft charging



1989 satellite data
showing global aurora



89 073 0151 UT

Space weather has many timescales and types of threats

- NOAA SWPC = Official sources of real-time data. Operational

- Pu

- O

- Ci

- D

- So

- W

- Aurorasaurus has specialized examples... simple. Not optimized for hams.

People also ask

What time will northern lights be visible tonight?



How high does KP have to be to see Aurora?



Is 2019 a good year to see Northern Lights?



Can I see the northern lights tonight in Michigan?



[Feedback](#)

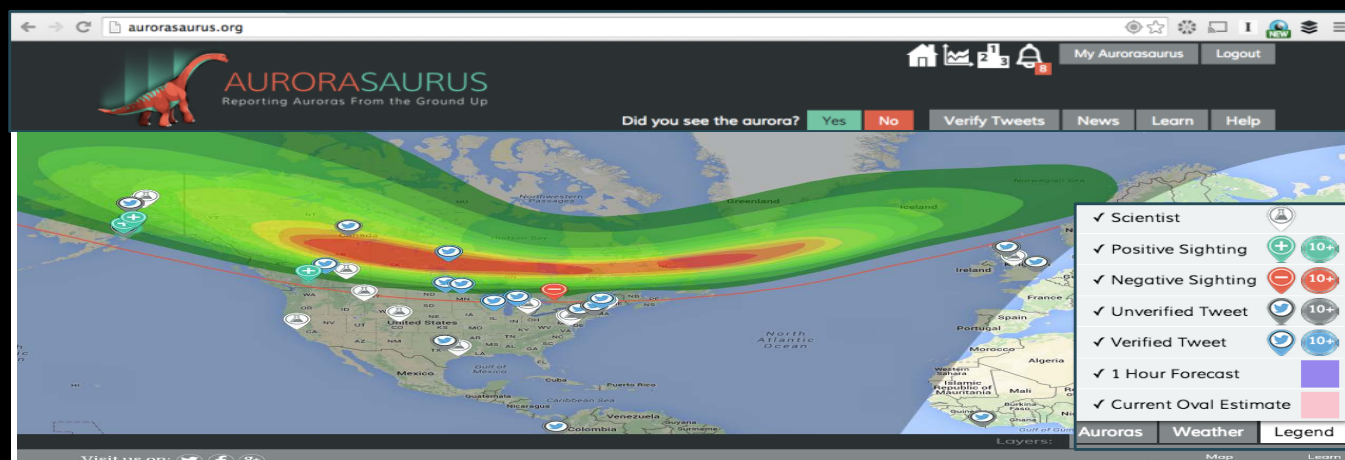
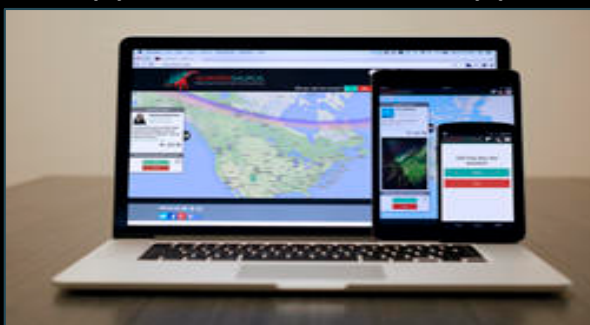
Space weather has many timescales and types of threats

- NOAA SWPC = Official sources of real-time data for US. Operational 24/7
 - Public are not paying customers of space weather data
- Difficult because space plasma physics generally starts in grad school
- Why aurora models have major limitations

Aurorasaurus

- Optical aurora is our specialty, skipping other aspects
- Citizen science forms the bridge (listening on both sides)
- Aurorasaurus has specialized examples... simple. Not optimized for hams.

Aurorasaurus.org
Apple iOS & Android apps



New global, real-time data sources from citizen scientists and tweets Alerts of auroral visibility for the public

Since 2014, our database has more than **7000** users, more than **7000** reports, and votes on more than **400,000** tweets.

Selected Papers (of >10 submitted so far)

MacDonald, E. A., et al., **Aurorasaurus: A citizen science platform for viewing and reporting the aurora**, Space Weather, doi: 10.1002/2015SW001214, 2015.

Case, N. A., et al., **Mapping Auroral Activity with Twitter**, Geophys. Res. Lett., 42, doi:10.1002/2015GL063709, 2015.

Case, N. A., et al., **Aurorasaurus and the St Patrick's Day storm**, Astronomy & Geophysics, 56 (3), 2015.

Case, N. A., E. A. MacDonald, and R. Viereck (2016), **Using citizen science reports to define the equatorial extent of auroral visibility**, Space Weather, 14, doi:10.1002/2015SW001320.

Tapia, A.; Lalone, Nicolas; (2014) **Crowdsourcing Rare Events: Using Beauty to Draw Participants into Science and Early Warning Systems**, 11th International Conference on Information Systems for Crisis Response and Management (ISCRAM). May 18-21, 2014



Citizen Scientist Images
March, 2016

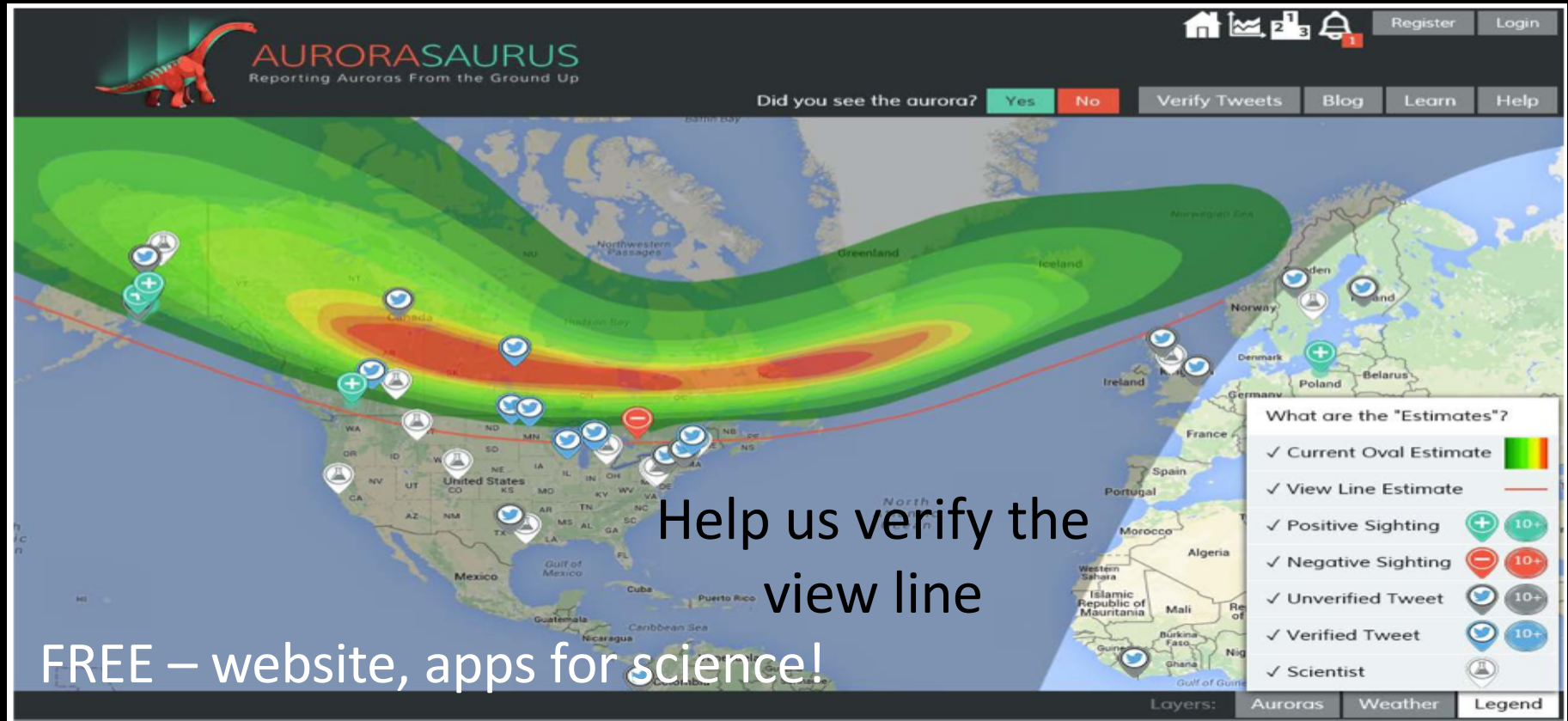


A new, open innovation, geospatial, crowdsourcing, open source platform and public-private partnership...

POC: Elizabeth MacDonald, e.a.macdonald@nasa.gov



How does Aurorasaurus.org work?



Help us verify the
view line

FREE – website, apps for science!

MacDonald et al., Space Weather, 2015

New global, real-time data sources from citizen scientists and tweets.



- Hybrid approach, twitter not required. Location required, privacy protected.
- Sign up to get a free, custom aurora alert for your location.
- When and where are critical pieces of information

Did you see the aurora?

Yes

No

Carrier 1:55 PM 100%

AURORASAUROS
Reporting Auroras From the Ground Up

Make a Report

Location:
Saskatoon, SK, Canada

When did your observation start?
19 Sep 2014 1:45 PM

When did your observation end?
19 Sep 2014 2:00 PM
☐ Ongoing?

What colors did you see?
☒ Red ☒ Green ☐ White
☒ Pink

Other:
Another color?

What type of aurora did you see?
☐ Discrete Arcs ☒ Diffuse Glow ☐ Patches (pulsating) ?

Other:
Something different?

Where in the sky was the aurora?
Northern Horizon Only

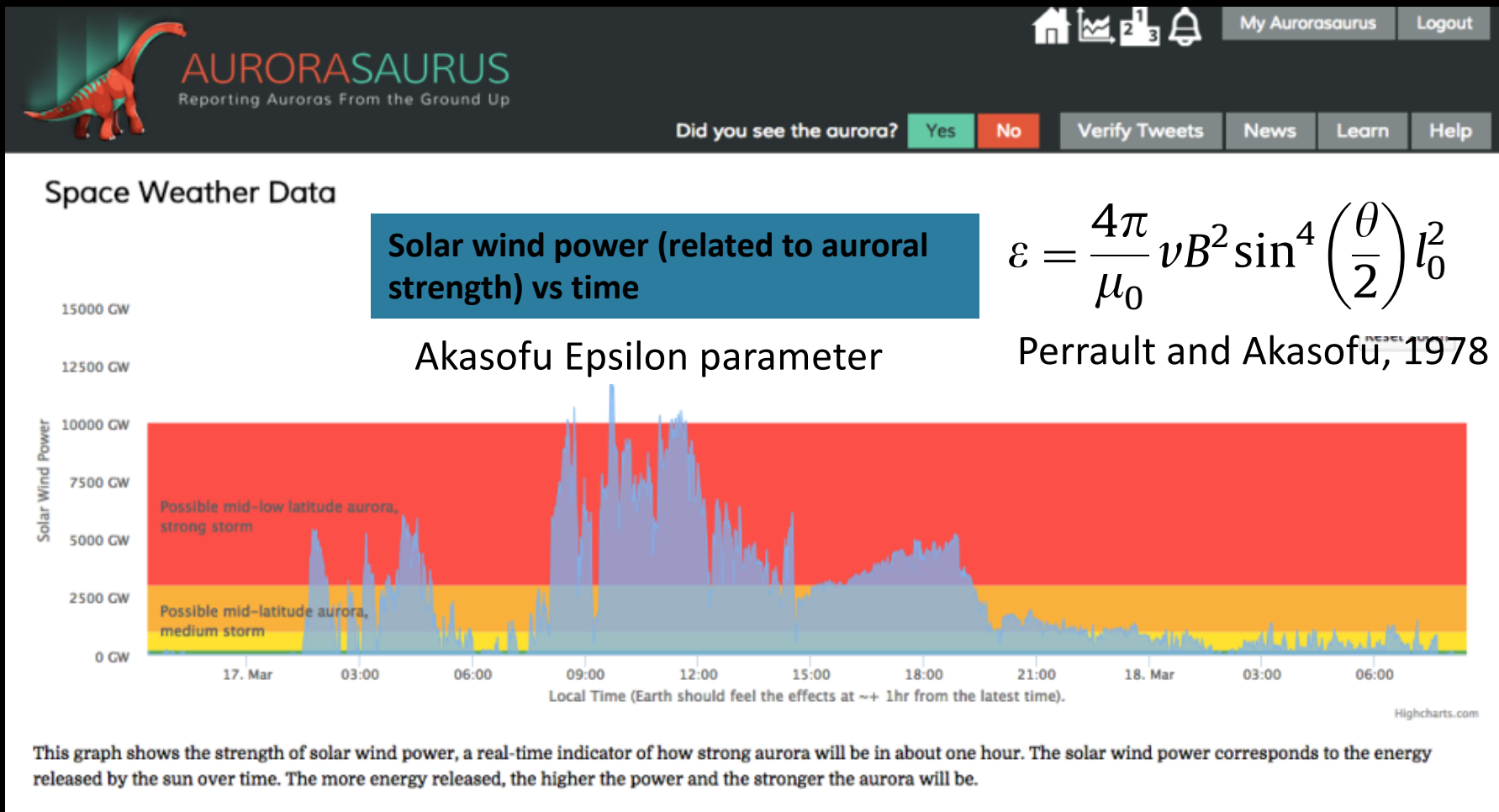
Other:
Something different?

How active was the aurora?

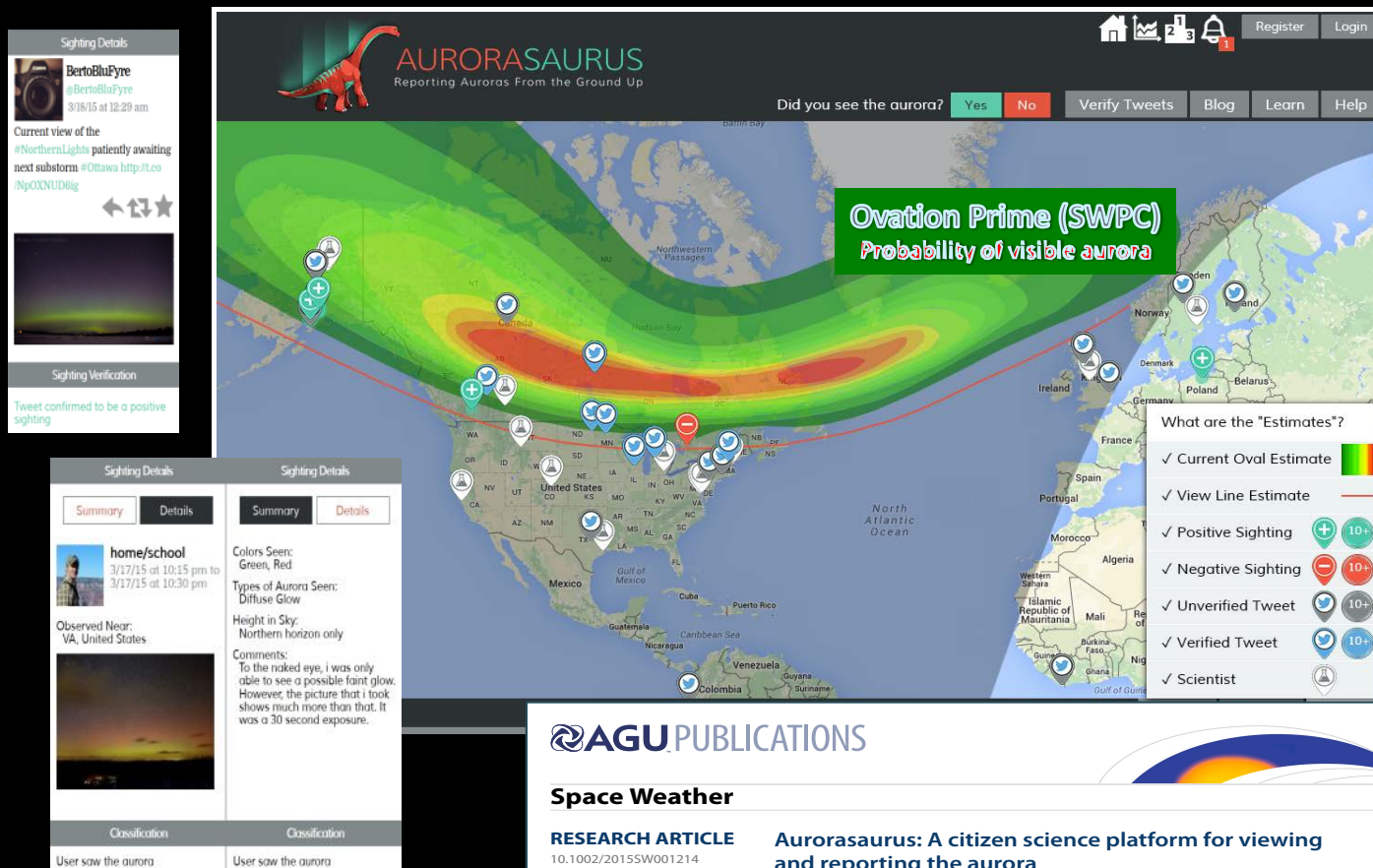
The indices probably won't help

- All the indices have issues and are mostly useful to characterize global activity
- Historical origin (not real-time)
- Kp index is global so not going to correlate to a local peak in aurora (big misconception)

Space science is core to our mission



Help us verify the view line



AGU PUBLICATIONS

Space Weather

RESEARCH ARTICLE
10.1002/2015SW001214

Key Points:
• Citizen science project collecting aurora observations

Aurorasaurus: A citizen science platform for viewing and reporting the aurora

E. A. MacDonald^{1,2}, N. A. Case^{1,2}, J. H. Clayton³, M. K. Hall³, M. Heavner^{1,4}, N. Lalone⁵, K. G. Patel^{1,2}, and A. Tapia⁵


Inputs: Verifying tweets, a crowd-sourcing data verification activity






CS: Classification

- Registered and anonymous users verify geotagged tweets by reading the tweet and voting “yes” or “no” if they think it is a real-time sighting at correct location
- Verified tweets used in alerts in conjunction with other observations

Sighting Details

 **Vonnie Valkyrie**
[@ybesser24](#)
8/23/15 at 1:29 am


Its so beautiful in the night sky the northern lights are dancing all over!
[#northernlights](#) [#Minnesota](#)





Did They Just See the Aurora?

Yes



No



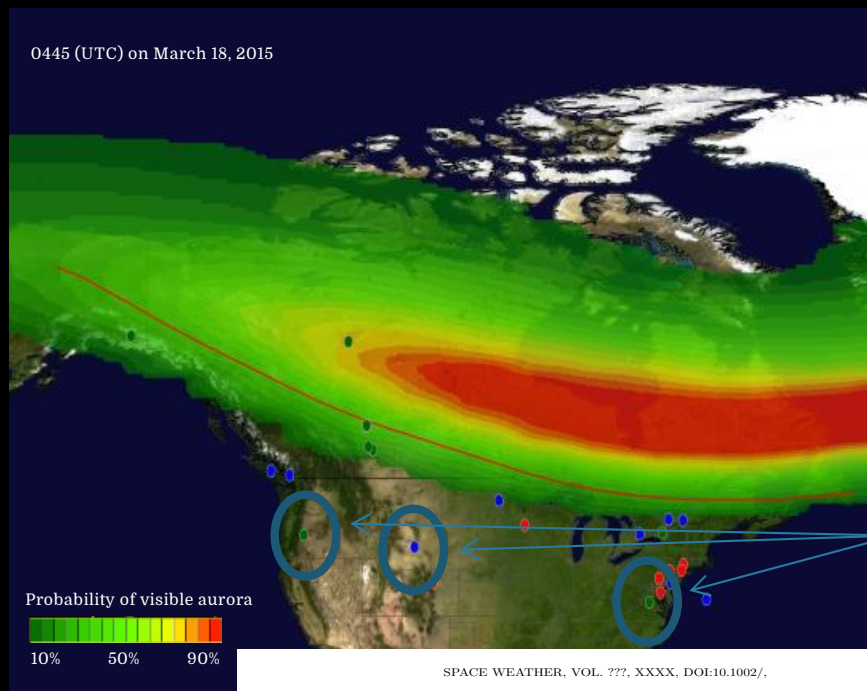
Citizen Science Aurora Data

Sighting Details	
<div>Summary</div> <div>Details</div>	<div>Summary</div> <div>Details</div>
 <p>home/school 3/17/15 at 10:15 pm to 3/17/15 at 10:30 pm</p> <p>Observed Near: VA, United States</p> 	<p>Colors Seen: Green, Red</p> <p>Types of Aurora Seen: Diffuse Glow</p> <p>Height in Sky: Northern horizon only</p> <p>Comments: To the naked eye, i was only able to see a possible faint glow. However, the picture that i took shows much more than that. It was a 30 second exposure.</p>
Classification	Classification
User saw the aurora	User saw the aurora

- Robust performance and database for large storms
- Open database

Sighting Details
 <p>BertoBluFyre @BertoBluFyre 3/18/15 at 12:29 am</p> <p>Current view of the #NorthernLights patiently awaiting next substorm #Ottawa http://t.co/NpOXNUD8ig</p> <p>← ↻ ⭐</p> 
Sighting Verification
Tweet confirmed to be a positive sighting

60% of our user's positive observations are below the view line during this event



1 Using citizen science observations to define the
2 equatorial extent of the visible aurora

N. A. Case^{1,2}, E. A. MacDonald^{1,2} and R. Viereck³

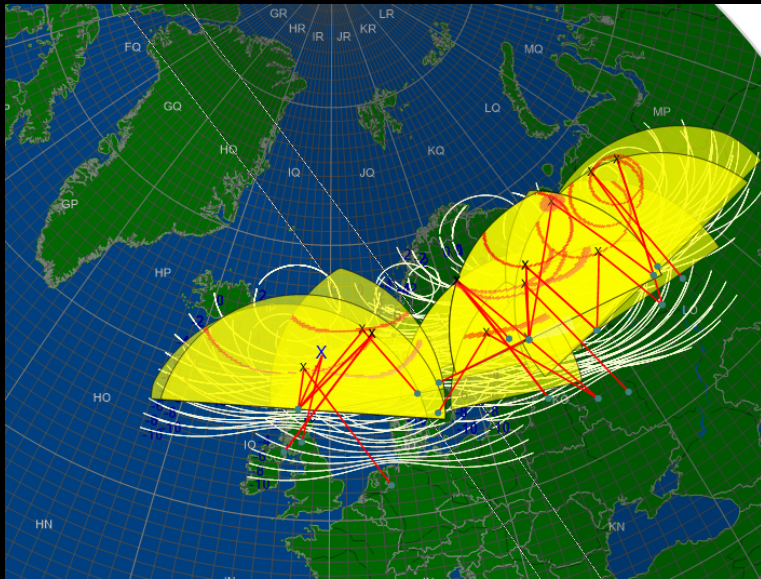
Aurorasaurus observations provide “ground-truth” for auroral models and estimates.

(left) Example OVATION Prime (2013) output for a 15min period in the St. Patrick's day (2015) storm. Green and blue dots indicate where the aurora was seen from.

Much further south than the model (and associated view line) predicts. **Substorms?**

Can test auroral precipitation estimates for visible aurora.

HamAurorasaurus ideas



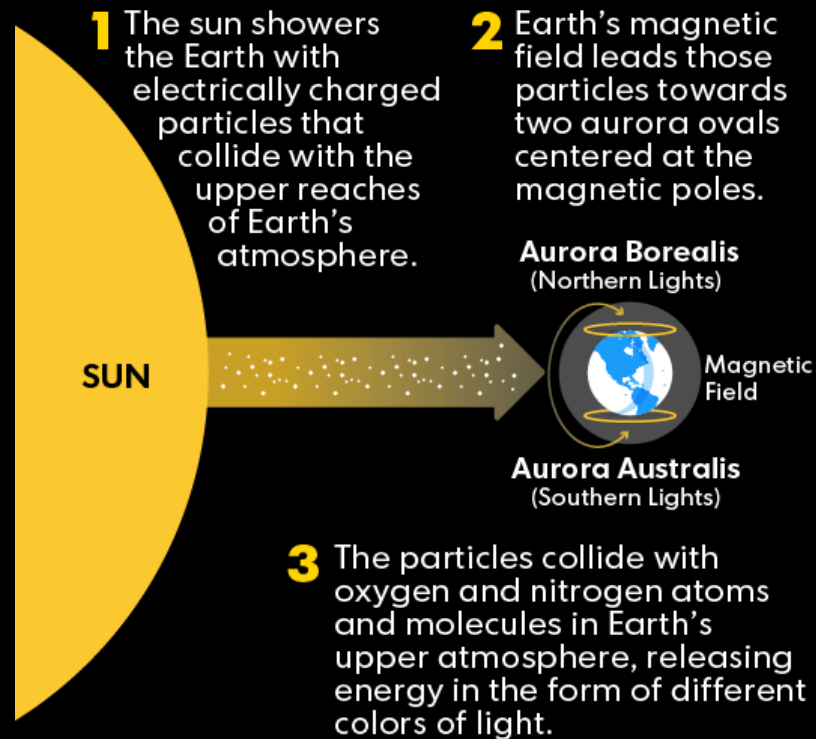
- Add additional radio-aurora specific questions
 - Absorption, Solar energetic particle events
- New map layer
- Science Questions
 - Does radio aurora map to structures? (coordination of different types of observers)
 - Can radio aurora map peaks or substorm onsets or unique features like STEVE?
- Can we do more together?
Communication
- Your suggestions please

Live radio map by G7IZU (Andy Smith), G7RAU (Dave Edwards)

#1 Myth

Aurora is formed by particles from the sun

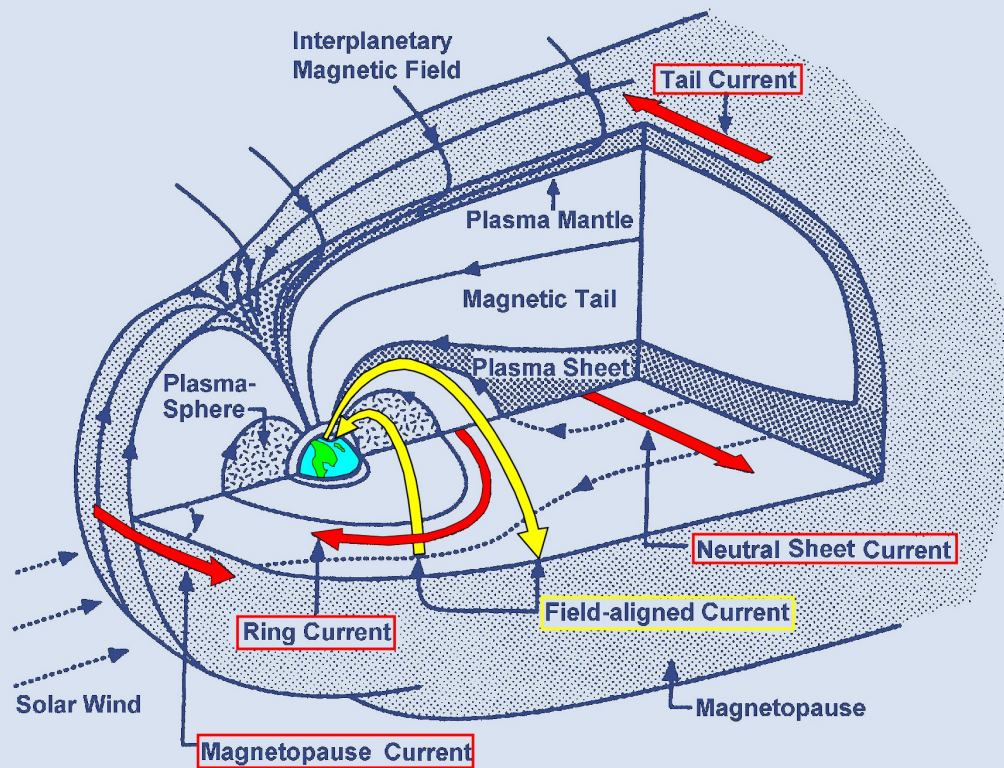
AURORA BOREALIS EXPLAINED



SOURCE Space Weather Prediction Center
Janet Loehrke, USA TODAY



Meet the magnetosphere!



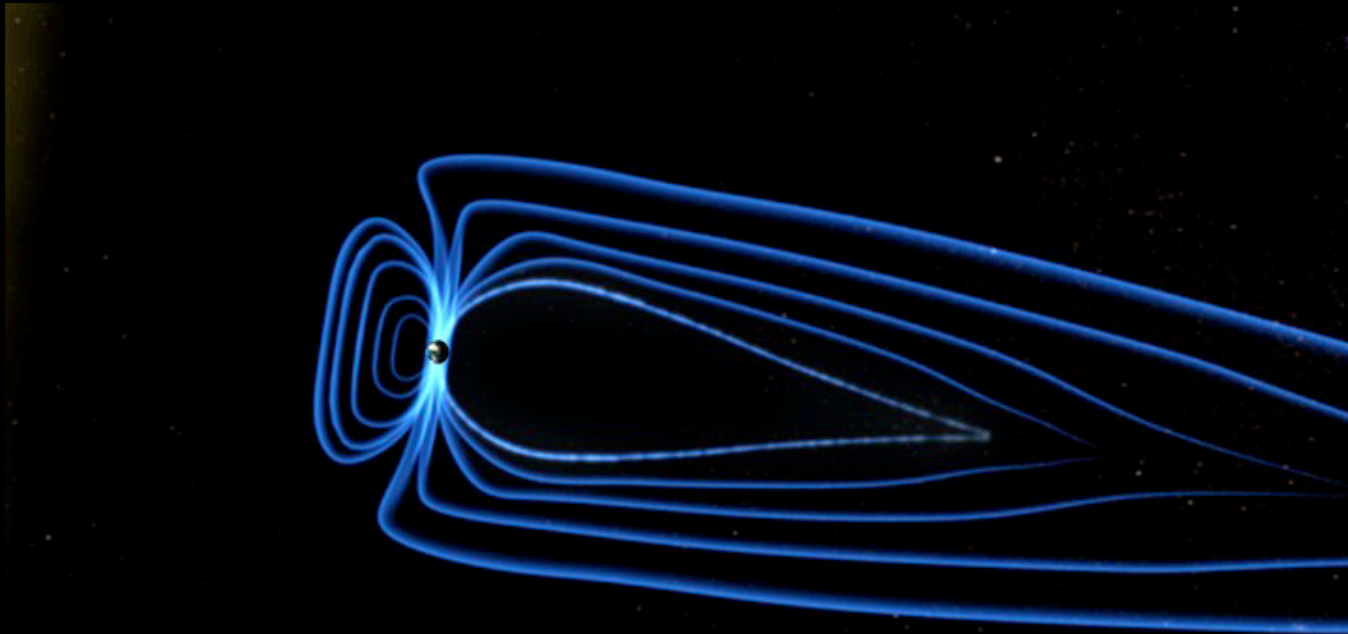
Calling Citizen Scientists Everywhere

Substorms do not look like substorms.

“If you’ve seen one storm, you’ve seen one storm.”

-Geoff Reeves

Myth No. 2
Aurora happens during storms



Everyday Aurora

(with lots of variation)

1. Quiet arcs to the northeast
2. Arcs intensify and stretch south and overhead, keep an eye for the southernmost arc to intensify, curls, beads, unusual features
3. Westward traveling surge and arcs expand to the north and south! (if after midnight may also see eastward motion)
4. Arcs begin to fade, patchy aurora occurs and whole thing resets and begins again

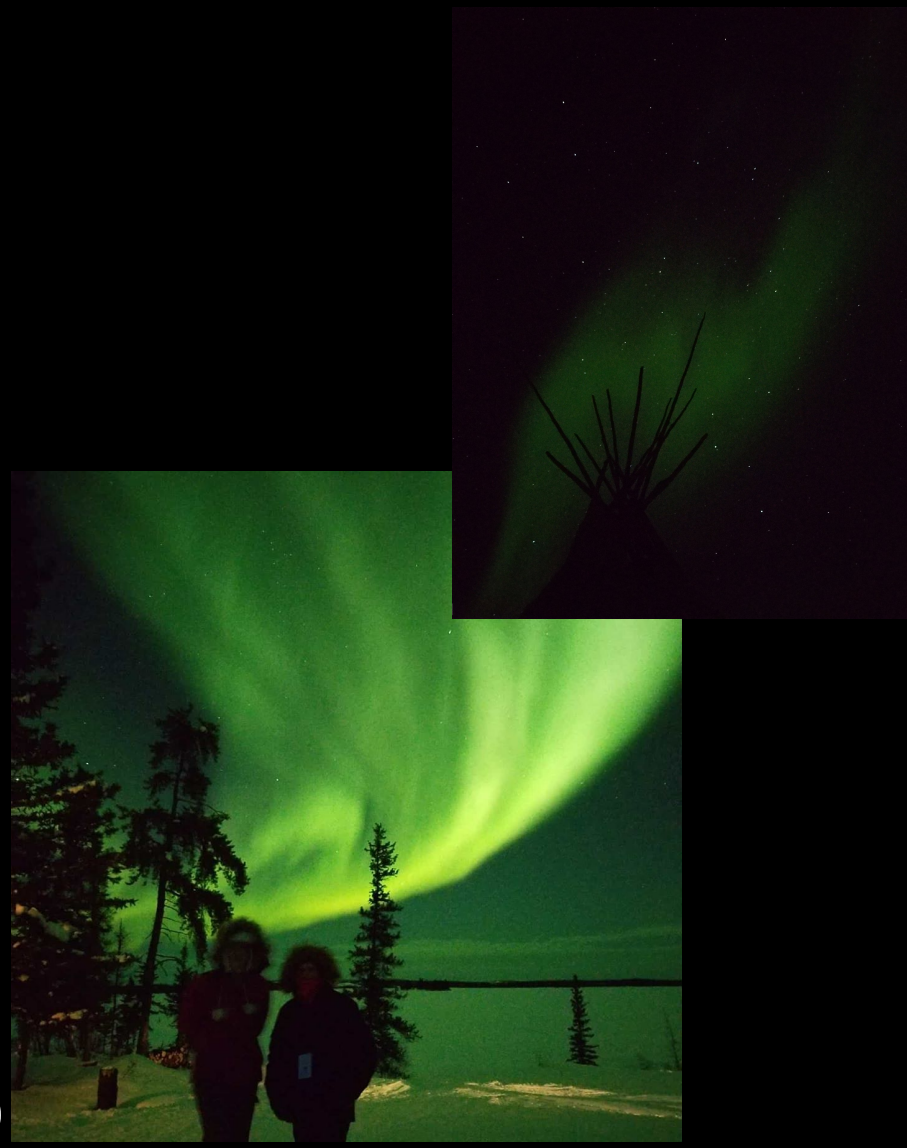
*technically called a substorm, first described by Akasofu (1964)
Growth phase, Onset or breakup, Expansion phase, Recovery



Everyday Aurora

1. Quiet arcs to the northeast
2. Arcs intensify and stretch south and overhead, keep an eye for the southernmost arc to intensify, curls, beads, unusual features
3. Westward traveling surge and arcs expand to the north and south! (if after midnight may also see eastward motion)
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Samsung Note 8 phone, Feb 2020



“Everyday aurora” Phenomenology of Auroral Substorm

Akasofu picture of the aurora during substorms:

- (a) Quiet auroral arc before substorm
- (b) Equatorward edge of aurora intensifies
- (c) “Westward traveling surge” forms
- (d) Poleward expansion of surge
- (e) Aurora begins to fade; patchy “pulsating aurora” forms on dawn
- (f) Auroral oval retreats to pre-substorm locations

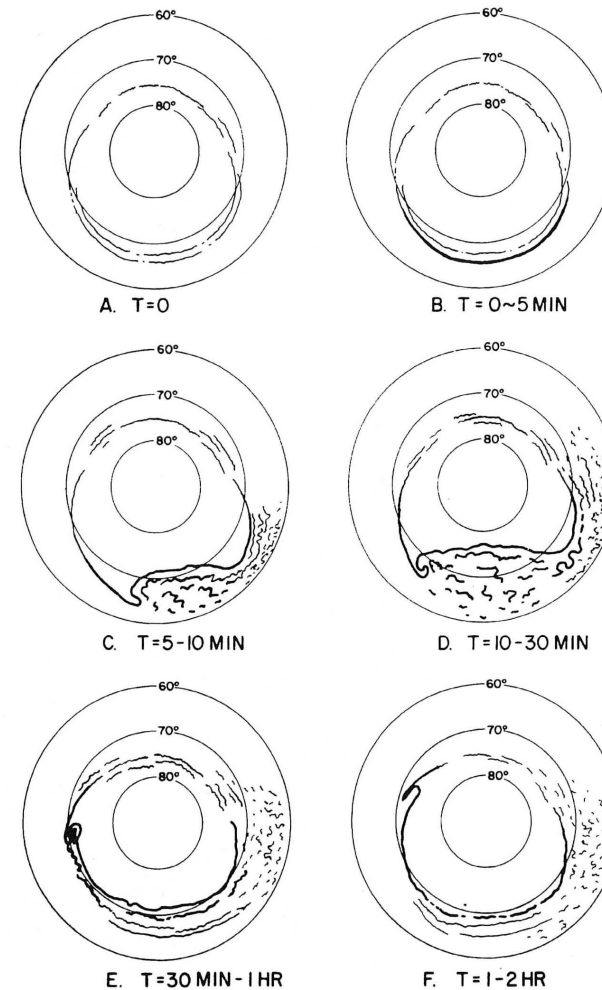


Figure 8. The schematic illustration to show how the auroral substorm develops and subsides.

Citizen science content on Twitter – different resolution to traditional cameras

Citizen Science Image of Unusual Auroral Beads

Ray Width (a) ~ 5 km
Ray Length (b) ~ 15 km
Bead Separation (c) ~ 20 km
Total Arc Size ~ 500 km
Dst = -128 nT

2015:12:21 05:01:58 UT

Taken from Saskatoon
Moon was in the sky
Exposure time: 2.5s
Lasted ~ 4 minutes

52° 5' 10" N, 106° 26' 2" W
2015:12:21 05:01:58 UT

Image credit Alan Duffy

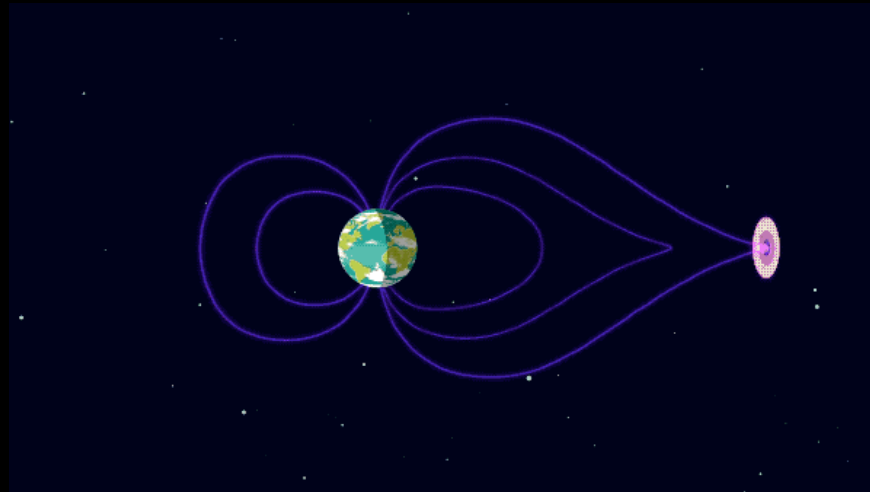
Blog link:
<http://blog.aurorasaurus.org/?p=398>



Meet STEVE

Photo credit: Paulo Fedozzi

The story of STEVE



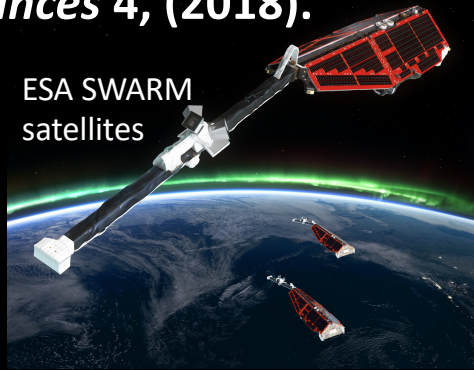
- NASA feature: <https://www.nasa.gov/feature/goddard/2018/nasa-needs-your-help-to-find-steve-and-heres-how>
- Eric Donovan's TEDxCalgary talk: <https://www.tedxcalgary.ca/talks/how-i-met-steve-discovery-new-aurora>
- Why it's really called Steve: <https://www.youtube.com/watch?v=amwaFNZYUUY>

New science in plain sight: Citizen scientists lead to the discovery of optical structure in the upper atmosphere, *Science Advances* 4, (2018).

2016-07-25 05:52:30 UTC

SWARM satellite track
measures particles flowing in
an SAID (subauroral ion drift)

ESA SWARM
satellites



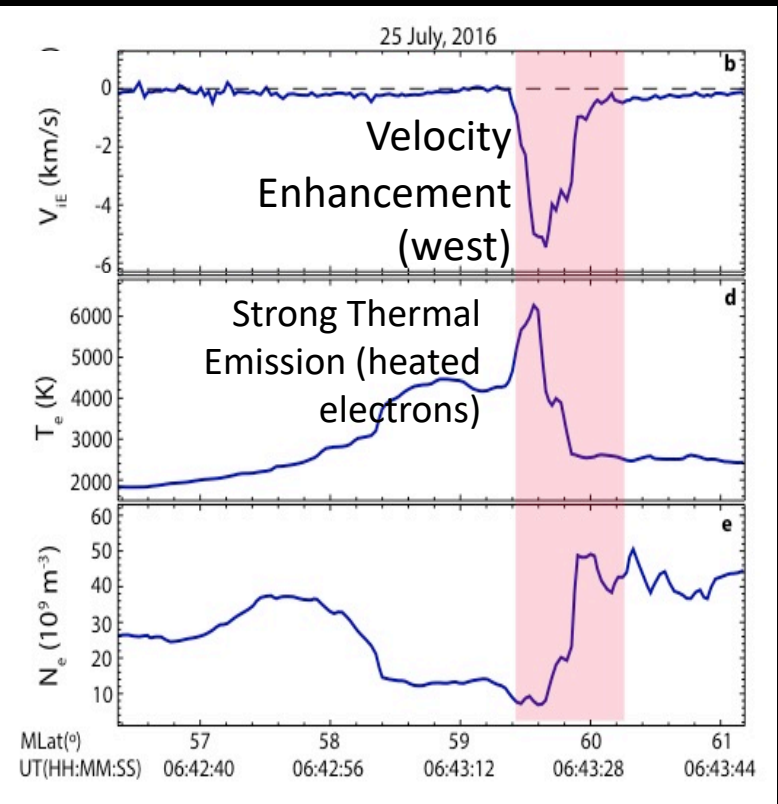
2016-07-25 06:03:51 UTC

Satellite +
ground-camera
array +
expert observers
in conjunction

Citizen science data

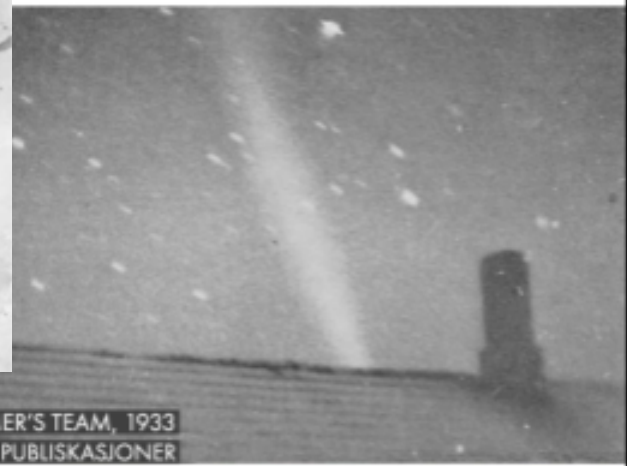
Notanee Bourassa, Aurorasaurus
Ambassador and Alberta Aurora
Chaser

Authors: E. A. MacDonald, E. Donovan, Y. Nishimura, N. A. Case, D. M. Gillies, B. Gallardo-Lacourt, W. E. Archer, E. L. Spanswick, N. Bourassa, M. Connors, M. Heavner, B. Jackel, B. Kosar, D. J. Knudsen, C. Ratzlaff, I. Schofield.



Hot off the press

- 100 yr old STEVE observations and papers have been uncovered by an amateur professional aurora historian in Germany
- Famous Norwegian scientist Carl Størmer researched “feeble homogenous arcs of great altitude”

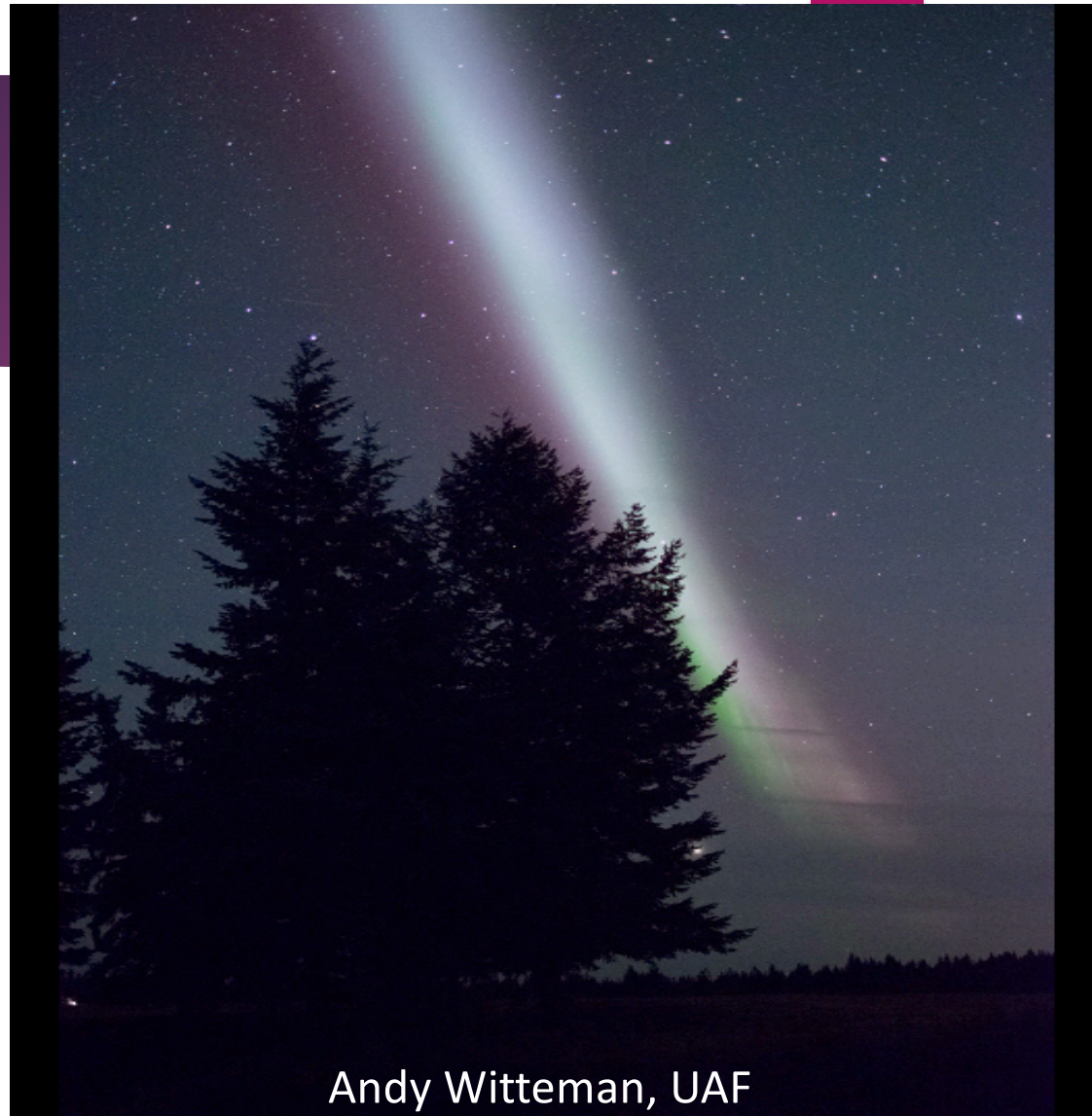


Hunnekuhl and MacDonald, Space Weather,
March 2, 2020

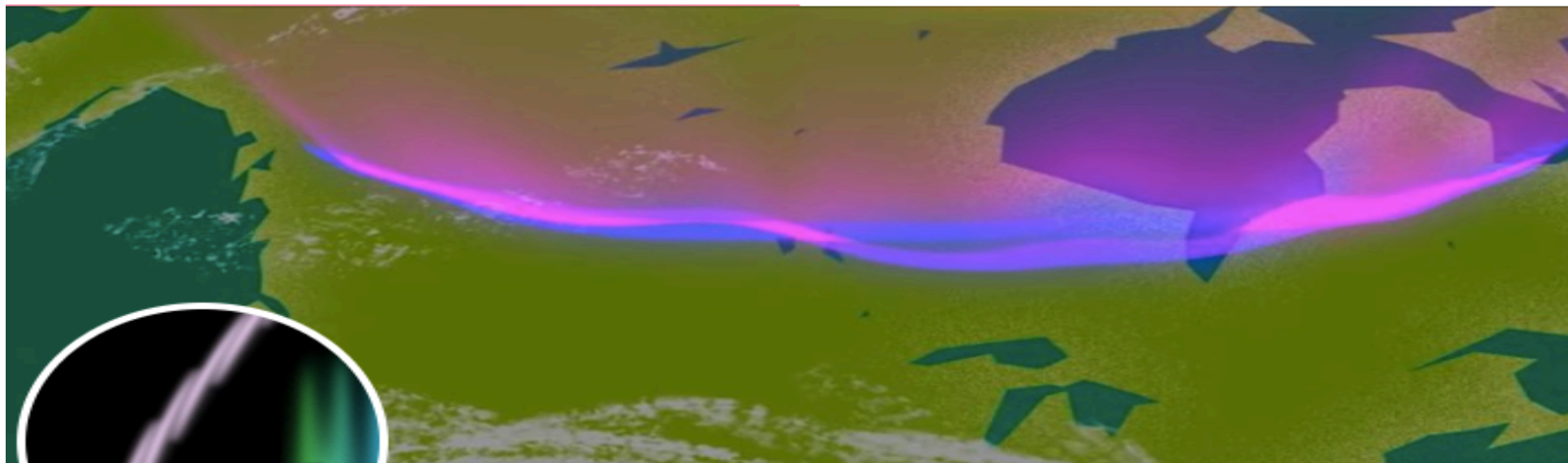
Top Photo: Størmer C. (1935). Remarkable Aurora-Forms from Southern Norway. I, Feeble Homogeneous Arcs of Great Altitude, Geofysiske Publikasjoner, 11(5)

What about the little
green facets?

- ▶ Fascinating
fundamental
plasma physics
MUST be explained.
Field lines not
vertical. Horizontal
and vertical drift.



Andy Witteman, UAF



Tweets **362** Following **164** Followers **419** Likes **1,409** Moments **1**

Phenomenal STEVE

@STEVEPhenomena Follows you

Just a misunderstood
[#StrongThermalEmissionVelocityEnhancement](#) glitter bomb from the Sun

advances.sciencemag.org/content/4/3/ea...

Joined September 2017

Tweets Tweets & replies Media

Pinned Tweet
Phenomenal STEVE @STEVEPhenomena · Mar 16



Meet Steve, a new type of northern lights

Science

The glowing ribbon of purple and green runs east-west in the sky. Citizen scientists in Canada weren't sure what



Photo Credit: Alexei Chernenkoff

Media coverage has helped recruit and reward citizen scientists

theWeather Club is part of the Royal Meteorological Society

THE 'AURORSAURUS' MAPS THIS YEAR'S SPECTACULAR AUORAS



WIRED

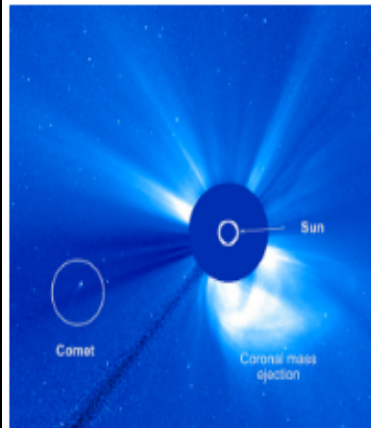
Smithsonian.com



GIZMODO

ScienceNews
MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

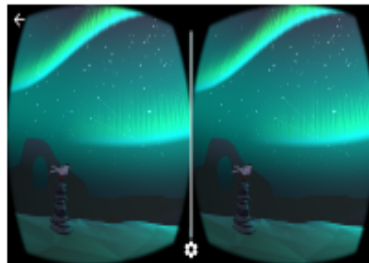




Space Weather at our Doorstep: How Can We Detect it?

Posted on *July 29, 2016*

Identifying Space Weather Phenomena Space weather is a complex field of study and can be a difficult term to define. According to NOAA's Space Weather Prediction Center (SWPC), space weather is described as the variations in the space environment between the sun and Earth. Other planets have space weather, too. In fact, we have been[...]



Check out Virtual Reality Aurora!

Posted on *November 1, 2016*

Aurora only occur in particular areas of the world and are highly unpredictable which are some of the reasons why many people feel fortunate to see them at all. And, for the majority of known human history, you could only experience the beauty and mystique

Aurorasaurus Tracks St. Patrick's Day storm on Social Media

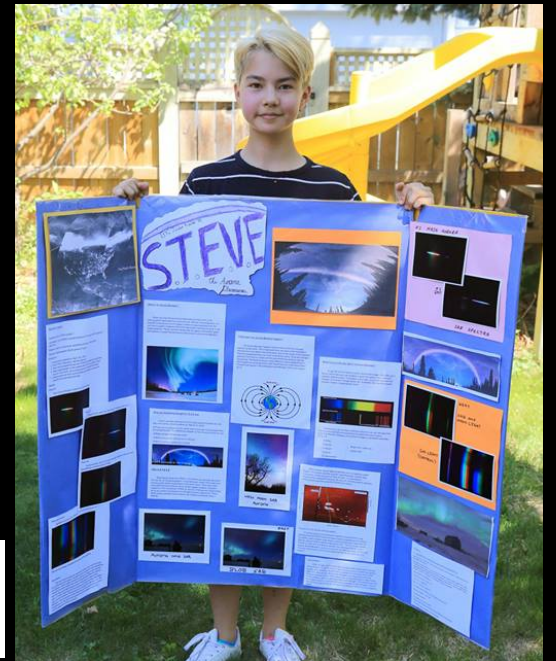
Posted on *March 19, 2015*

By Nathan Case and Kasha Patel An Aurorasaurus user submitted this photo of the aurora in Germany along with a report. On Tuesday, March 17, 2015, as people adorned themselves with green clothing and infused their livers with green beer, Earth was experiencing the biggest geomagnetic storm of the last decade—leading to beautiful,



For Kids

- Wow in the World podcast on STEVE aurora
- Classroom webinar with Hearts in the Ice (Aurorasaurus on YouTube)
- Blog posts on DIY aurora, science fair, and high school activities
- Handouts and activities



For Adults



- US on Vimeo in April, Citizen Science Month

- Blog, newsletter, make reports, verify tweets
- Webinar with author Melanie Windridge "Auroras: In Search of the Northern Lights" (YouTube)
- Educational & Ambassador opportunities

How a man behind the 'Steve' discovery used the Northern Lights to cope with life

Notanee Bourassa immersed himself in aurora borealis as a way to escape his troubles. One night, he saw something new and amazing.

by Meagan Campbell Mar 18, 2018

MACLEAN'S



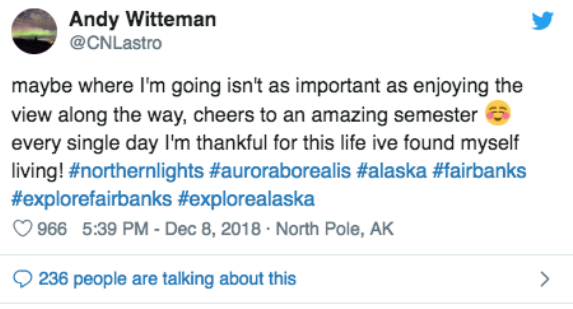
Free resources for further study

Largely qualitative low jargon introduction

Mostly at undergrad level

- Interactive learning module, good graphics of physics, get free account
 - Physics of the aurora: <http://www.meted.ucar.edu/hao/aurora/>
 - Space Weather basics: <http://www.meted.ucar.edu/spaceweather/basic/>
- Book: Storms from the Sun: free download
 - <https://www.nap.edu/catalog/10249/storms-from-the-sun-the-emerging-science-of-space-weather>
- Article: The Location of the Polar Aurora, RJ Livesey, 1980, available on ADS (Aurorasaurus journal club soon)

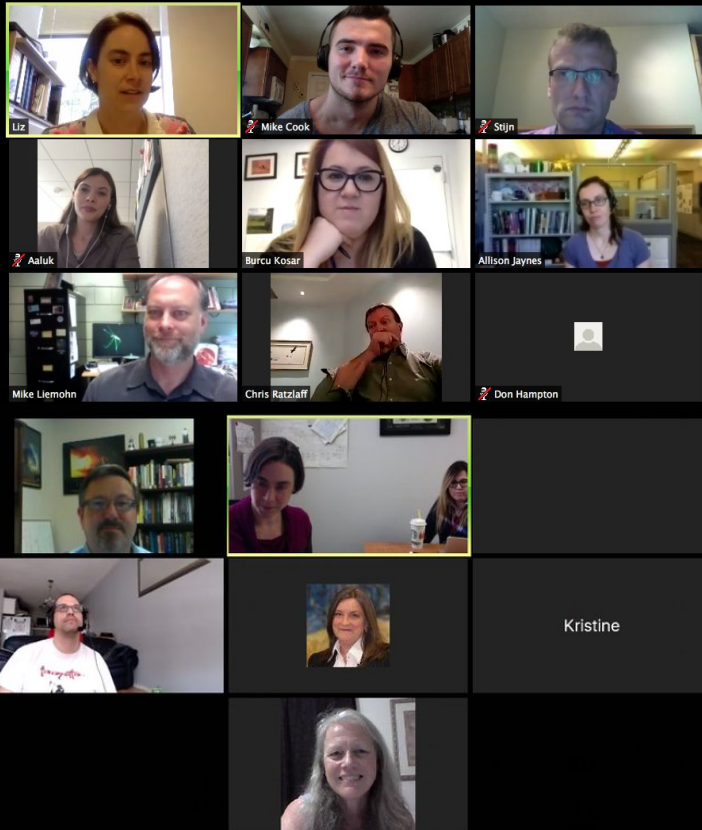
For Researchers



- STEVE & Aurorasaurus papers & ongoing research
- Citizen science in Decadal Survey and NASA policy
- Ambassador opportunities, join Twitter and share your science!
- Postdoc opportunity

The future is bright – join us!

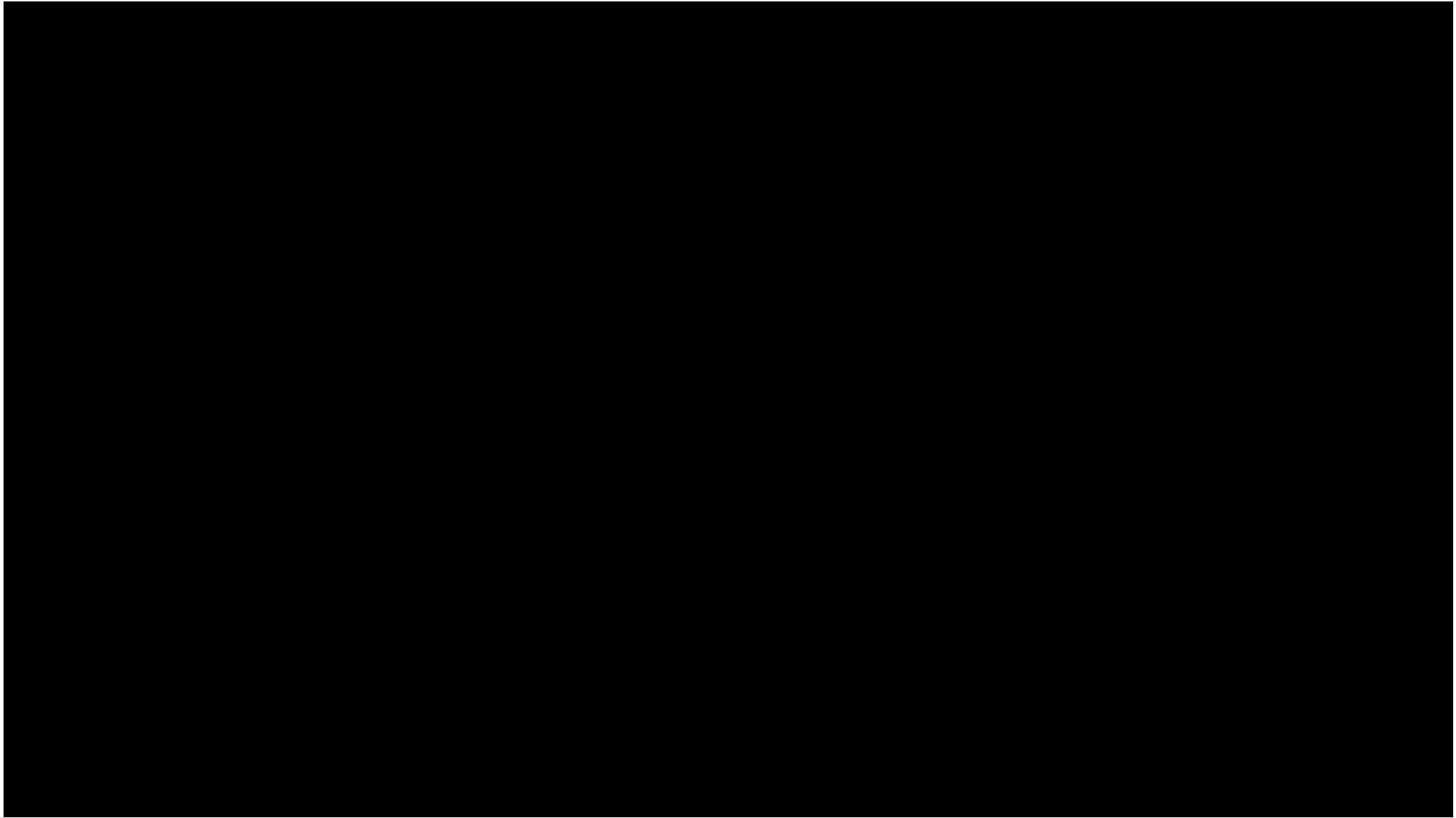
- Next solar max with new cell phones
- Renewed interest in satellite auroral imaging
- NASA encouraging citizen science @DoNASAScience



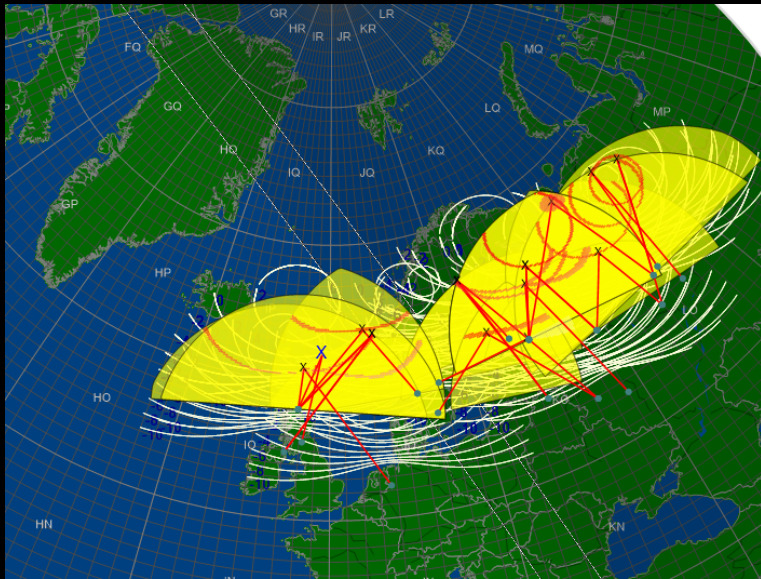
Ambassadors



Samsung Note 8, Feb 2020



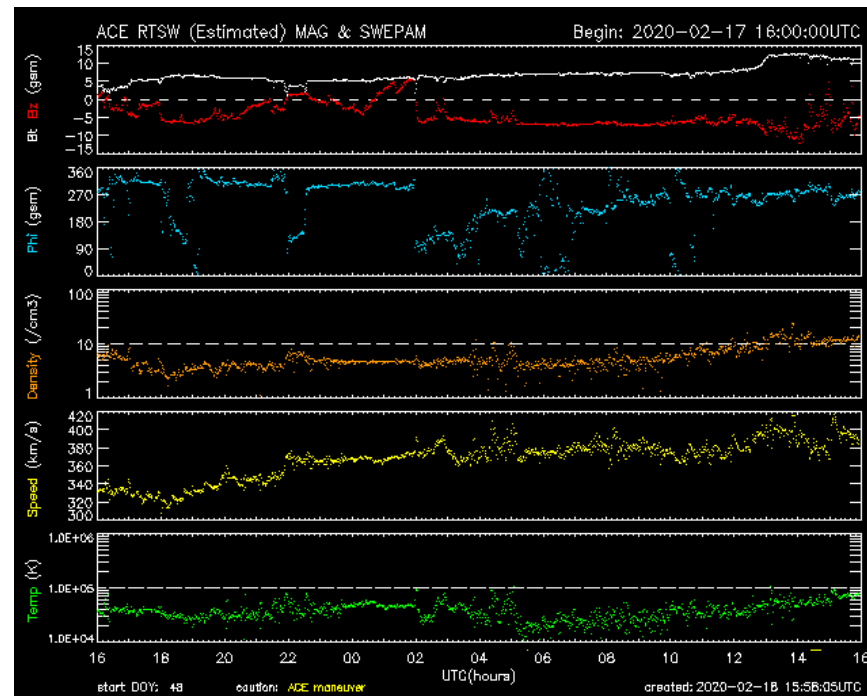
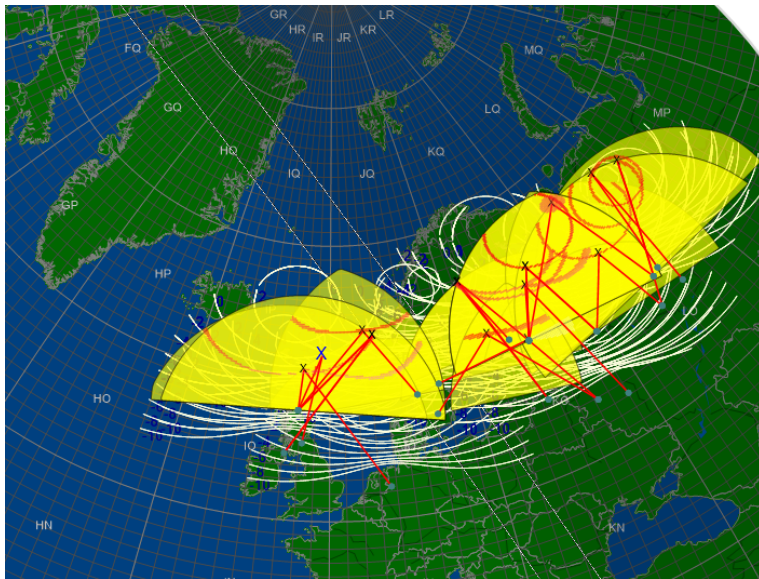
HamAurorasaurus ideas



- Add additional radio-aurora specific questions
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- Science Questions
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- Your suggestions please

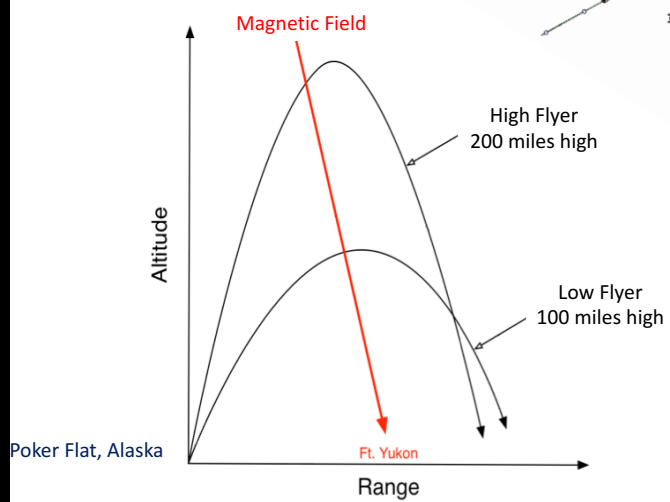
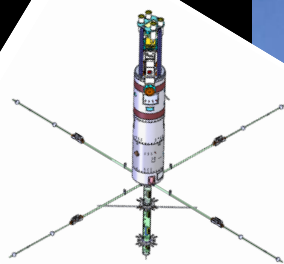
Live radio map by G7IZU (Andy Smith), G7RAU (Dave Edwards)

Live radio map by G7IZU (Andy Smith), G7RAU (Dave Edwards)

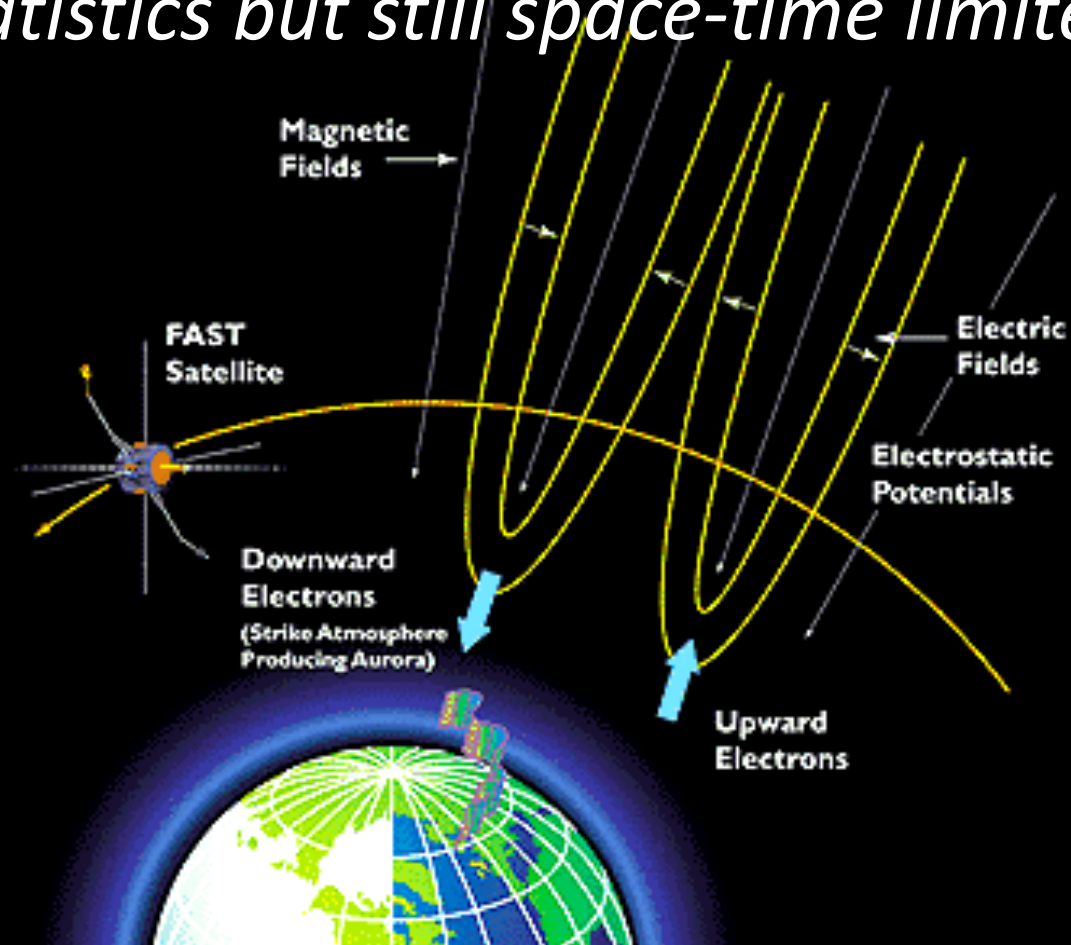


HamAurorasaurus?

- ▶ Add additional radio-aurora specific questions
 - ▶ Absorption, Solar energetic particle events
- ▶ New map layer
- ▶ Science Questions
 - ▶ Does radio aurora map to structures? (coordination of different types of observers)
 - ▶ Can radio aurora map peaks or substorm onsets or unique features like STEVE?
- ▶ Can we do more together? Communication
- ▶ Your suggestions please



Now from satellites...
statistics but still space-time limited



“Everyday aurora” Phenomenology of Auroral Substorm

Akasofu picture of the aurora during substorms:

- (a) Quiet auroral arc before substorm
- (b) Equatorward edge of aurora intensifies
- (c) “Westward traveling surge” forms
- (d) Poleward expansion of surge
- (e) Aurora begins to fade; patchy “pulsating aurora” forms on dawn
- (f) Auroral oval retreats to pre-substorm locations

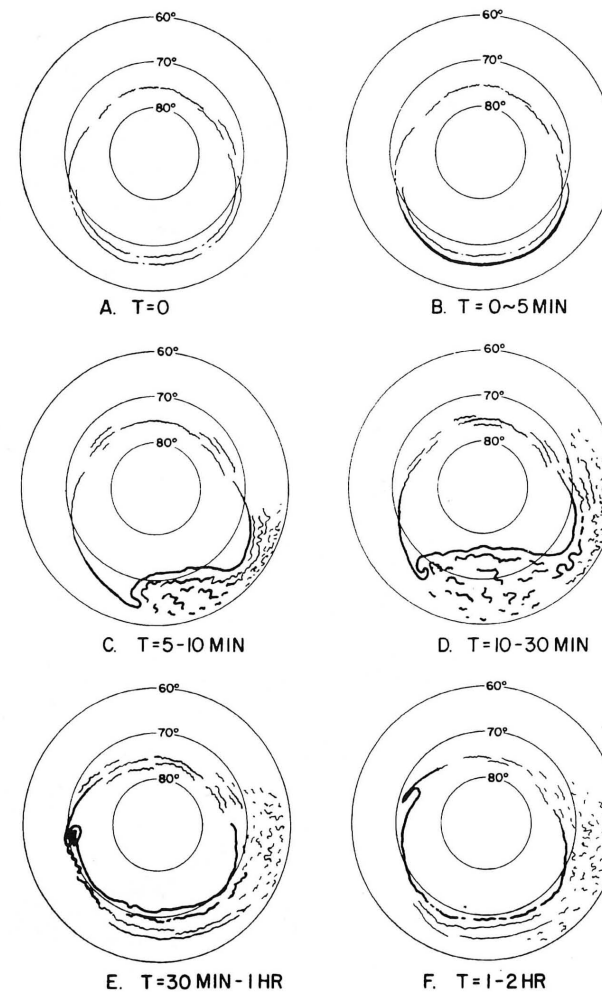
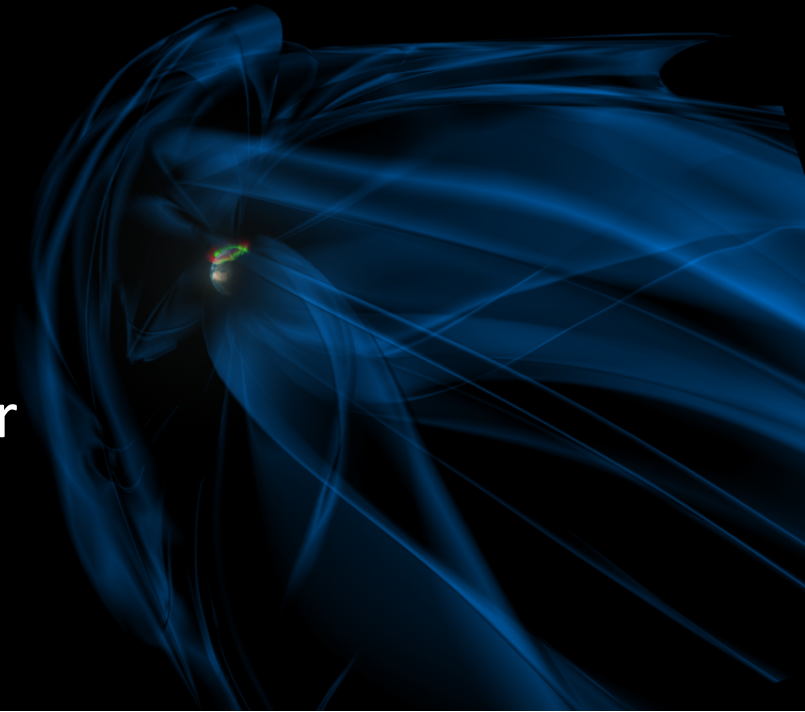


Figure 8. The schematic illustration to show how the auroral substorm develops and subsides.

What we now know

- Citizen science lets us see differently
 - Mapping a dynamic boundary in 3d space
- We have different siloed regions and much jargon between them
- What else are we missing?
- Increasing resolution with people power





Let's start with the story

- Traditional science missed something
- Timelapse photos at lower than usual latitudes enable a different viewpoint



The New York Times

SCIENCE

That Ghostly, Glowing Light Above Canada? It's Just Steve

WHAT is the significance of STEVE?

► Prof. Larry Lyons UCLA, quoted in The Atlantic:

"It is truly exciting, to us as aurora scientists, that there is a group of amateurs out there who enjoy the aurora so much that they could put together something that is this new to us. That's just unbelievably cool."

"I've never seen something this new discovered by citizen scientists in the aurora before."

"Finding something you can identify as a new structure in the aurora is relatively unusual. The last major thing was poleward boundary intensification, and you can find that name used back over 20 years ago."

Photo credit: Megan Hoffman ©, fm photography

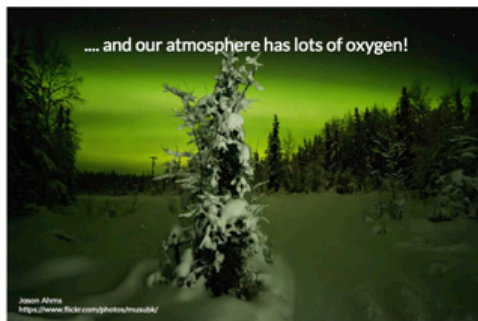
WHY is green the most common color for an aurora?



Aurora can appear in many colors, but green is the most common. You may have seen an eerie green glow in the sky or in a science fiction movie.

SciFi has it right and here's why!

The green light comes from excited oxygen atoms...



While nitrogen is the most common element in our atmosphere, oxygen is the most common element at the altitude where aurora occur (100 - 500 km).



You may recall that excited oxygen atoms can emit red or green light, depending on how much extra energy they have. So, why aren't red aurora more common?

It's all about timing and collisions.

When two atoms collide, energy is transferred between them.



If an oxygen atom is excited to the energy level corresponding to green...

... and it has no collisions...

... then it will emit light after 1 second.

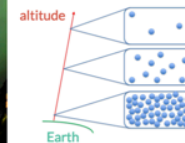
If an oxygen atom is excited to the energy level corresponding to red...

... and it has no collisions...

... then it will emit light after 110 seconds.



It may seem short to you, but 110 seconds is a long time for an excited oxygen atom to avoid collisions!



Blue, pink, and violet may also appear, especially near the lower boundary of aurora, due to higher levels of nitrogen below 100 km. But these colors are much less common than green.



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Citizen science as disruptive innovation

- Project to reach out to amateurs as a way to help with our problem of a dearth of data



Calling
Citizen
Scientists
Everywhere!

Help NASA track
the aurora at
Aurorasaurus.org

Join the
conversation
with @tweetaurora
and download
the iOS, Android apps
aurorasaurus.info@gmail.com



Inspiration

**CROWD
SOURCING
WEEK**
Powering Breakthroughs Together

“**Scientists and government** s can now engage with their stakeholders on a completely new level, through more than just social media interactions, and can actually work together to create value for everyone. Crowdsourcing is where social media turns into **scientific** productivity.”

Epi Ludvik Nekaj

Founder & CEO, Crowdsourcing Week

- ▶ Can you apply this to space? Democratizing science. Authentic science learning.
- ▶ Is citizen science changing NASA?

Myth No. 1 – how aurora forms

